SOUTHWEST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE

SOUTHWEST FISHERIES CENTER

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MAY 1987

DIRECTOR'S REPORT
To The
THIRTY-EIGHTH TUNA CONFERENCE
On
TUNA AND TUNA-RELATED ACTIVITIES
At The
SOUTHWEST FISHERIES CENTER
LA JOLLA, CALIFORNIA

For The Period
MAY 1, 1986 To APRIL 30, 1987

ADMINISTRATIVE REPORT LJ-87-08

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SWFC ADMINISTRATIVE REPORT NO. LJ-87-08

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INTRODUCTION

As reported to you last year, tuna research in the National Marine Fisheries Service was restructured in 1985. The Southeast Fisheries Center in Miami was given responsibility for all NMFS research in support of the International Commission for the Conservation of Atlantic Tunas; the Southwest Fisheries Center responsibility for all NMFS research for the Indian Ocean, western and central Pacific and any Federal efforts associated with the eastern tropical Pacific. "This division of responsibilities," wrote Dr. Joseph Angelovic, NMFS Assistant Administrator for Science and Technology, "follows the geography-related principles that underlie our fisheries objectives system."

In response to Angelovic's mandate and cognizant of the significant changes which have occurred in the world tuna fishing industry and particularly in the U.S. tuna fishery in the past several years, the SWFC identified four major goals for a tuna research program which will meet national needs for research and management and assist the U.S. tuna industry to improve their ability to compete internationally. The goals we have developed for the Center's tuna program are set forth in greater detail on the following pages.

Although this was a year of change and transition, it was also a year of accomplishments in tuna and tuna-related research at the Southwest Fisheries Center. For example, we began an ambitious 5-year research program designed to monitor trends in abundance of dolphin killed incidentally to fishing operations by the U.S. purse seine fishery for tropical tunas in the eastern tropical Pacific. The first survey was planned and carried out over a 5-month period, using two NOAA research vessels that crisscrossed the Pacific for a total of 43,000 nautical miles. The survey provided information on dolphins as well as for a broad spectrum of ocean studies, including the watch of the El Niño.

Scientists from the Center's Honolulu and La Jolla Laboratories joined colleagues from New Zealand, Tonga, the Cook Islands and France for a three-ship survey of the albacore resource in a band of water called the Subtropical Convergence extending from Chile to New Zealand about 2,400 miles south of the Equator. Commercial fishermen who assisted in the survey by tagging fish and taking oceanographic measurements, made excellent catches of albacore in the area (up to 10 tons per day). NMFS fishery experts believe that the excellent potential of the South Pacific fishery is a fortuitous circumstance for U.S. fishermen who have been experiencing lower catch rates in the North Pacific.

In other developments in tuna research, the Honolulu Laboratory sponsored a workshop to revitalize the Hawaii aku industry, studies were conducted on billfish behavior and vulnerability to commercial and recreational fishing gears, methods were developed to use information collected by observers on tuna vessels to monitor changes in the relative abundance of dolphins in the eastern tropical Pacific, skipjack and mahimahi were tracked with ultrasonics, studies were conducted on the role of natural mortality in tuna models, the Center was involved in the development of an archival tag for tuna, and many others.

During the past year, 22 papers were published on tuna and tuna-related subjects, including publication of the Proceedings of the International Commission for the Conservation of Atlantic Tunas Conference on the International Skipjack Year Program, edited by Gary Sakagawa of the SWFC.

The report which follows here is not intended as a comprehensive account of our work on tuna and tuna-related subjects, but rather as an informal statement of major activities and events.

The information was compiled by Lillian Vlymen and Jean Michalski, Technical Writers/Editors on my staff, from material supplied by Center scientists at laboratories in Honolulu, La Jolla, and Monterey (Pacific Fisheries Environmental Group), and by the staff of the Southwest Region in Terminal Island, California.

Izadore Barrett

Izadore Barrett, Director
NMFS Southwest Fisheries Center

May, 1987
La Jolla, California

THE U.S. TUNA INDUSTRY IN 1986

In a reversal of recent trends, U.S. cannery receipts[1] of imported and domestically-caught albacore (white meat) and tropical (light meat) tunas (skipjack, yellowfin, blackfin, bluefin, and bigeye tuna) rose sharply in 1986, reaching 523,651 short tons (tons), an increase of 12% from 1985 (Figure 1). Cannery deliveries by domestic vessels totaled 243,913 tons, up 6% from 1985, while imports of raw tuna rose 16% to 296,548 tons. With the increase in raw tuna supplies, the total pack of canned tuna by U.S. processors reached 32.7 million standard cases[2], up 17% from 1985. On the other hand, imports of canned tuna continued to increase during 1986, and the U.S. tuna fleet underwent a further reduction.

In the U.S., skipjack, yellowfin, bigeye, and bluefin tuna are collectively canned as light meat tuna. The 6.5-ounce can of chunk style, light meat tuna in water has in recent years been the most popular tuna product consumed in the U.S. The domestic pack of all light meat products totaled 24.6 million standard cases in 1986, a gain of 16% from 1985. The total cannery supply of raw light meat tuna--domestic deliveries plus imports--for 1986 was 407,832 tons, up 11% from 1985, but 4% below the 1981-85 annual average.

At the beginning of 1986, the U.S. tropical tuna fleet consisted of 110 vessels with an overall carrying capacity of 99,594 tons. By year end, the fleet had experienced a 20% loss in numbers, and a 7% decline in capacity. Despite the reduction in fleet, receipts of domestically-caught, light meat tuna totaled 223,666 tons in 1986, 8% above receipts for 1985. This total comprised 90,605 tons of skipjack tuna and 133,061 tons of yellowfin tuna (includes bigeye, bluefin and blackfin tuna), an 8% jump in skipjack deliveries and an increase of 8% in yellowfin deliveries from 1985. In addition to deliveries to U.S. canneries, U.S. flag vessels exported[3] 31,304 tons of light meat tuna to foreign canneries in 1986, down 10% from 1985. When exports are combined with domestic deliveries to U.S. canneries, total U.S. deliveries were 254,970 tons, 5% greater than the corresponding amount for 1985.

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[1]Cannery receipts include only tuna destined for U.S. canneries. Cannery receipts exclude U.S.-caught tuna landed at foreign sites, U.S.-caught tuna landed at U.S. sites that is destined for foreign canneries, U.S.-caught tuna destined for the fresh-fish market, tuna imported as flakes, imported tuna not fit for human consumption, and imported "sushi" grade tuna.

[2]A standard case consists of 48 6.5-ounce cans or 19.5 pounds.

[3]Exports include tuna landed directly in or transshipped to a foreign country; excludes tuna exported from U.S. east coast.

Imports of light meat tuna increased 15% in 1986, reaching 184,166 tons. Imports of yellowfin amounted to 79,135 tons, up 17% from 1985. Skipjack made up the balance of light meat imports increasing 13% from 1985.

Albacore, which is the only species that may be canned as white meat tuna in the U.S. accounted for approximately 25% of the total U.S. canned tuna pack in 1986. The total cannery supply reached 115,819 tons in 1986, 14% above receipts for 1985 and 17% above the 1981-1985 average. The domestic pack of white meat tuna for 1986 amounted to 8.1 million standard cases 30% above the pack in 1985.

The volume of domestically-caught albacore delivered to U.S. canneries in 1986 totaled 3,527 tons, 49% less than the amount in 1985. U.S. cannery receipts of imported raw albacore totaled 112,292 tons in 1986, an 18% increase from 1985. Imports accounted for 97% of the 1986 total cannery supply compared with 93% in 1985.

The western Pacific Ocean[4] was the primary production area for the U.S. fleet in 1986, providing 143,777 tons--56% of the domestically-caught cannery receipts and direct exports for the year--an 8% increase in western Pacific deliveries from 1985. The western Pacific was also the area from which most of the raw tuna imports originated in 1986, 67,900 tons, 23% of total imports by oceanic area.

Not only was the U.S. canned tuna pack up from 1985, canned imports set a new volume record in 1986, reaching 12.1 million standard cases. This represents a 11% increase from 1985 and an increase of 170% since 1981. Imports were dominated by tuna packed in water which is subject to a much lower import duty than tuna packed in oil. When canned imports were combined with U.S. production, the total addition to U.S. canned supplies in 1986 was 44.8 million standard cases, up 15% from 1985.

No action was taken on legislation introduced into the U.S. House of Representatives during 1985 which was aimed at eliminating the tariff difference between imports of canned tuna in water and canned tuna in oil. However, as requested by the U.S. Trade Representative, the International Trade Commission conducted a "332 investigation" during 1986 for the purpose of gathering, presenting, and analyzing information on the competitive and economic factors affecting the performance of the U.S. tuna industry (U.S. International Trade Commission, 1986). Unlike the Commission's 1984 "201 investigation" (U.S. International Trade Commission, 1984), the 332 study was not conducted in response to a petition for import relief, and therefore did not require a determination on the Commission's part as to whether such relief was warranted.

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[4]The eastern and western Pacific for this report are distinguished at 150°W longitude.

The retail composite canned tuna price, which decreased 2% in 1985, fell an additional 2% during 1986. The downward price trend contributed to corresponding growth in overall apparent consumption which increased approximately 5% in 1986, following a 3% increase for all of 1985. On the fresh fish front, landings and sales of U.S. fresh and fresh-frozen tuna products continued to improve during 1986.

Termination of Mexican Tuna Embargo

Of particular interest with regard to light meat tuna imports in 1986, was the termination, in August, of the embargo on U.S. imports of Mexican-caught tuna , which was instituted in July 1980 after the seizure of U.S. tuna vessels within Mexico's 200-mile territorial fishery zone. Recognizing the potential economic stress that an inundation of exports could impose on the U.S. tuna industry, Mexico agreed voluntarily to limit its exports of tuna products to the U.S., which would presumably consist mainly of frozen light meat tuna, to the following maximum levels beginning September 1, 1986:

2-month period ending	Volume tons (round weight equivalent)
August 31, 1987	19,290
August 31, 1988	24,802
August 31, 1989	30,314

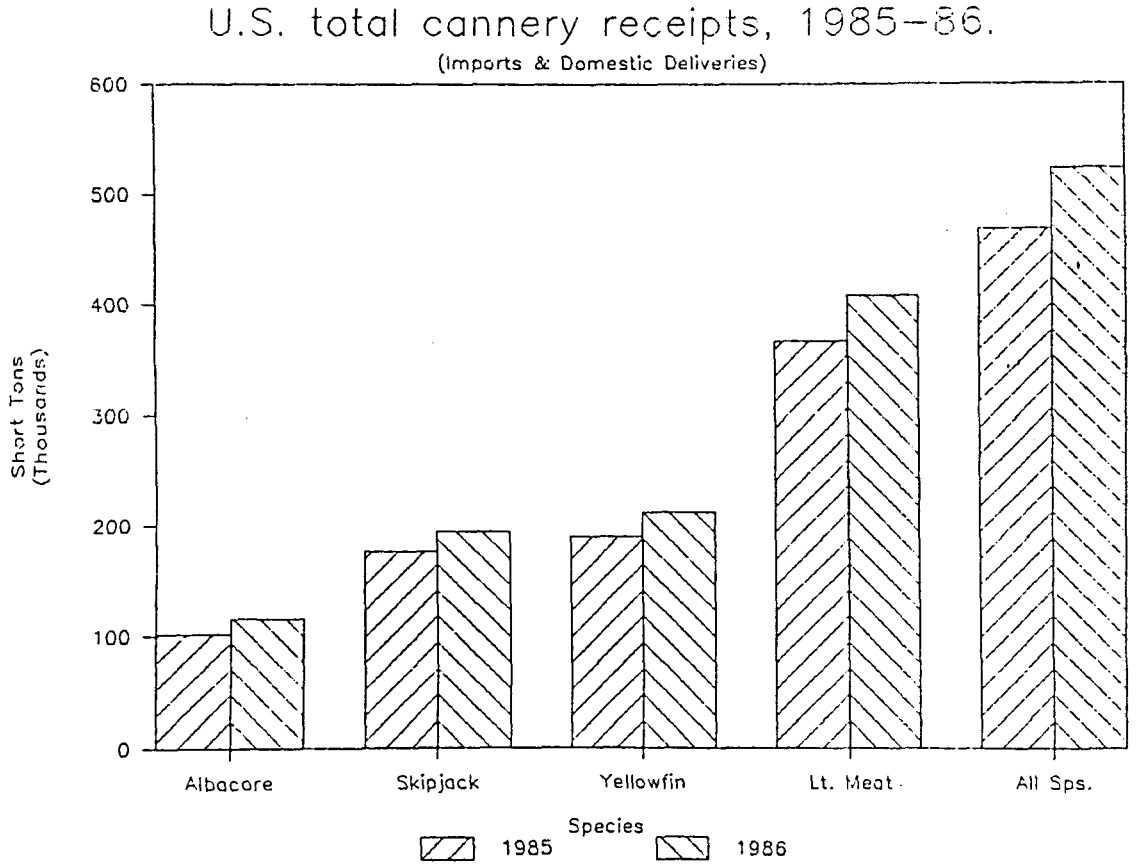
(Source: Office of Fisheries Affairs, U.S. State Department.)

After August 31, 1989, there will be no voluntary restraint on imports.

Since frozen tuna delivered to U.S. processors is, for the most part, a homogeneous commodity, an increase in supply from one source will have an impact on the demand, and price received for frozen tuna from all other sources. The immediate effect of Mexico redirecting its exports of frozen tuna to the U.S. will probably be price reductions in the U.S. market for frozen tuna. Because U.S. tuna fishermen have relatively few ex-vessel market alternatives, they will bear the brunt of any price reductions. On the other hand, confronted with lower prices in the U.S. market, foreign (non-Mexican) suppliers will likely divert their exports to other foreign markets that are relatively unaffected by the increase in U.S.-Mexico trade.

Lower ex-vessel prices translate into reduced processing costs for U.S. canners. To the extent that Mexican exporters redirect their shipments to the U.S. market, there will probably not be a decline in the price of frozen tuna in non-U.S. markets. Under these circumstances, U.S. processors experience a competitive advantage vis-a-vis foreign processors in the domestic canned tuna market, thereby providing U.S. processors an

opportunity to increase their market share. If this occurs, increased output by domestic processors simply displaces imports of canned tuna and there is little net effect on prices.



CHANGES IN LONGLINE FISHERY STRATEGY DOCUMENTED

Southwest Fisheries Center scientists Gary Sakagawa, Atilio Coan, and Norman Bartoo have completed a manuscript, "Patterns in longline fishery data and bigeye tuna catches," which details the historical shifts in fishing global strategy by the major longlining nations and examines the causal factors. Results indicate that in the Japanese longline fishery, fishing strategy changed from albacore to bigeye tuna as the target species in response to economic pressures.

These pressures include increased operating cost, low albacore prices, and high prices for bigeye tuna for sashimi-grade fish. The results are supported by evidence that albacore catch rates have remained at high levels that were experienced by the japanese fishery before the shift, and the shift occurred in the Pacific, Atlantic, and Indian Oceans approximately simultaneously.

IN SUPPORT OF EXISTING

INTERNATIONAL AGREEMENTS

INDO-PACIFIC TUNA

Although there is little participation at present by U.S. fishermen in Indian Ocean fisheries, the area of the Indian Ocean continues to be of interest as potentially productive and as a source of tuna to meet growing demand. In recent years, French and Spanish tuna seiners have moved into the area where they are experiencing high catch rates. As traditional tuna stocks begin to be more fully exploited and catch rates decrease, the potential for greatly increased landings of various tunas in this part of the world ocean will become more important and attractive to U.S. fishermen.

At the Southwest Fisheries Center in Honolulu, Hawaii and La Jolla, California, scientists maintain an active involvement in fisheries research in the Indo-Pacific through regular participation in meetings and workshops sponsored by such International organizations as the Indo-Pacific Fishery Commission (IPFC), the Indian Ocean Fishery Commission (IOFC) and FAO.

In December, 1986, Gary Sakagawa, Chief of the Pelagic Fisheries Resources Division traveled to Colombo, Sri Lanka to attend meetings on tuna resources in the Indian Ocean. The first meeting was organized by the Indo-Pacific Tuna Development and Management Program (IPTP), at which he delivered two papers.

The 35 participants in the IPTP expert consultation meetings reviewed information on the state of Indian Ocean tuna stocks and fisheries development. The fastest developing fisheries are for tropical tunas, yellowfin and skipjack tuna, which are caught by vessels of coastal and distant-water nations. The 1985 catch was approximately 243,000 metric tons (mt), an increase of 26% over 1984. Although the coastal nations are concerned over this rapid development (primarily over increased rivalry between coastal artisanal fishermen and the high-seas purse seine fleets) the stocks appear to be healthy and capable of sustaining further increases in exploitation.

Catches of other principal tuna species (bigeye, albacore, and southern bluefin) amounted to about 84,000 metric tons in 1985; the fisheries for these species are primarily with longline gear, employed by vessels of Japan, Korean, and Taiwan. The southern bluefin tuna stock is overexploited, whereas the bigeye and albacore stocks appear to be fully exploited without much scope for increased catches with the longline gear.

The secondary tuna and tuna-like species, or "small tunas," are important sources of protein and employment for fishermen of the coastal nations of the Indian Ocean. In 1985 about 212,000 mt of small tunas were caught primarily by artisanal fishermen. Longtail tuna and seerfishes are the primary species exploited and are high on the list for further fishery development by the

coastal nations. No information is available on the state of these stocks.

The second meeting was organized by the Indian Ocean Fishery Commission (IOFC) and involved members of the Committee for the Management of Indian Ocean Tuna. Representatives from France, Japan, Korea, Maldives, Mauritius, Mozambique, Seychelles, Spain, Sri Lanka,Tanzania, Thailand and the U.S. participated in the IOFC Committee meeting. Actions adopted by the committee were: 1) recommended continued collection of fishery statistics and conduct of research on stock structure, biology and stock assessment; 2) recommended funding of $1.25 million be secured for a Tuna Fisheries Interaction Programme; 3) made minor wording changes to project document for cost-sharing (55% United Nations Development Program (UNDP), 45% countries) of 1987-89 budget of $1.05 million total for IPTP; 4) established committee (France, Japan, Sri Lanka, Thailand and Seychelles and EEC as observer) to develop options for the future of IPTP activities after 1989 when UNDP funding terminates; and 5) elected Sri Lanka to chair committee and Mauritius and Spain to provide vice chairmen. The next session of the committee will probably be held in Mauritius, pending formal invitation from that government.

INTERNATIONAL SKIPJACK YEAR PROGRAM VOLUME PUBLISHED

The Proceedings of the International Commission for the Conservation of Atlantic Tunas (ICCAT) Conference on the International Skipjack Year Program was published in October, 1986, a significant contribution to the literature on this subject. Forty-five papers presented at the Conference, which was held in Santa Cruz, Tenerife, Spain, from June 21 through June 29, 1983, make up the core sections of this publication. This volume represents the completion of the Skipjack Year Program and the attendant research that was carried out by ICCAT over a period, 1979-1983.

The work program was carried out under the auspices of the International Commission for the Conservation of Atlantic Tunas. Gary Sakagawa, Chief of the Pelagic Fishery Resources Division at the La Jolla Laboratory, served as the convener of the committee that organized and planned the research program, and as the co-editor of the final, 388-page volume. Scientists from the Southwest Fisheries Center contributed six research papers to the volume.

U.S.-SOUTH PACIFIC ISLANDS REGIONAL FISHERIES TREATY, 1987

During the past several years, the U.S. tuna fleet has been fishing extensively in the Western Pacific Ocean. This region has now become a significant fishing area for the tuna fleet,

although its traditional fishing grounds in the eastern Pacific remain important as well.

The U.S. neither claims nor recognizes jurisdiction over highly migratory species beyond 12 nautical miles from the coast. However, all Pacific Island states claim jurisdiction over tuna to 200 nautical miles from their coasts. This jurisdictional dispute has resulted in the seizure of two U.S. tuna vessels in the western Pacific in recent years. Both incidents triggered retaliatory embargoes by the U.S., as mandated by the Magnuson Act, on imports of tuna products from the seizing nations.

To resolve these problems, the U.S. began to negotiate a regional licensing agreement with 16 Pacific Island States in 1984. After the negotiations began, the region took on increased importance and urgency when the Soviet Union successfully negotiated a fisheries access agreement with the island nation of Kiribati and began to make overtures to other countries in the region.

On April 2, 1987, representatives of the U.S. and Pacific Island States signed a 5-year regional fisheries agreement in Port Moresby, Papua, New Guinea; Charlie Fullerton, director of the NMFS Southwest Region in Terminal Island, California, was among those attending the signing ceremony.

Under the agreement terms the U.S. will pay the Pacific Island states $60 million over 5 years for fishing rights and provide additional economic assistance. The U.S. tuna fishing industry will contribute $10 million in license fees and technical assistance over the same period. The United States (NMFS) has responsibility for enforcing the provisions of the treaty and licenses issued under it. The agreement will enter into force as a treatu after ratification by the U.S. and 10 Pacific Island states.

The following statement, presenting the U.S. position on the treaty, is excerpted from a U.S. Department of State Press Release:

"We believe that the agreement is a very good one from the point of view of the U.S. industry and fishermen involved in the region. The regional nature of the agreement makes a great deal of operational and practical sense from the fishermen's point of view. The U.S. tuna industry will pay at least $2 million per year for this access. It has guaranteed the purchase of 35 regional licenses at $50,000 each ($1.75 million) in the first year of the treaty, plus provide $250,000 in technical assistance to the FFA (acting as agent for the Island States). Up to 5 additional licenses (to a total of 40) may be purchased for $50,000 each; 10 further licenses (up to a total of 50) may be purchased for $60,000 each. In future years of the agreement, license fees will be indexed to the average price of yellowfin and bigeye tuna. However, the annual cost of an individual license will not drop below $50,000 per vessel. In an associated

agreement, the U.S. Government (USG), through AID, will provide $10 million annually for 5 years, in economic support to the Island States.

The USG assistance, called for by this agreement, responds to the long-standing U.S. government commitment to assist in the economic development of these democratic, pro-western Island States. Parties to the treaty are: Australia, the Cook Islands, the Federated States of Micronesia, Fiji, Kiribati, the Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, the Solomon Islands, Tonga, Tuvalu, Vanuatu, Western Samoa, and the U.S. We expect the treaty will come into force during the summer or fall of 1987."

The agreement also provides for the submission of logbooks by U.S. flag vessels fishing under the terms of the agreement. The Southwest Fisheries Center is developing plans to process these logbooks after they are collected by NMFS Southwest Regional Office staff. The major landing site will be Pago Pago, American Samoa; other offloading sites include Agana, Guam and Tinian Island in the Commonwealth of the Mariana Islands. Additionally, biological data will be collected from the catch to aid in resource assessment studies.

IN SUPPORT OF POSSIBLE FUTURE INTERNATIONAL AGREEMENTS

NORTH PACIFIC ALBACORE

Summary of the 1986 North Pacific Albacore Fishery

An estimated 11,338,940 pounds (5,143 mt) of albacore were landed in ports throughout California, Oregon, and Washington in 1986, a decrease of 35% from the 17,484,820 pounds (7,931 mt) landed in 1985. No landings were reported from Hawaii for 1986. Even though albacore fishing was less successful in 1986, excellent offshore catches were reported early in the season throughout May and June in areas 400-500 nautical miles (nm) northeast of Midway Island, and throughout August in areas 500 nm due west of Newport, Oregon. Catch per unit effort (CPUE) as high as 99.0 and 183.0 fish per standard day respectively were reported taken by jigboats in these two areas. Fishing inshore in 1986 started late in June with significant catches throughout July off southern California.

Favorable environmental conditions located between a sub-arctic and a weak sub-tropical front offshore (along the 35°N parallel) from May to June may have contributed to the success of the jigboats fishing in areas northeast of Midway Island. Strong coastal upwelling inshore throughout August and September may have helped provide good fishing in areas along the coast from Point Conception, California to Cape Blanco, Oregon. However, the highest catch rates for the 1986 season were taken 500 nm west of Newport, and may have resulted from a rapid increase in sea surface temperatures throughout August in these areas.

Approximately 59% of the total albacore catch was sampled for information on effort and catch, and 2% was sampled for length-frequency. The average size of albacore caught in 1986 was 69.8 cm (15.4 pounds) which was slightly larger than the average size in 1985 of 69.1 cm (15.0 pounds). Fishing effort (4,253 days) in 1986 was significantly lower than those reported (7,725 days) in 1985. Estimated annual catch-per-unit effort for a standard 45-foot vessel in 1986 was 117.0 fish per day, which was much higher than the 82.0 fish per day in 1985. The 45% decrease in fishing effort may have contributed to a much higher annual CPUE in 1986.

The information on the 1986 North Pacific albacore fishery was compiled by Fishery Biologist Anthony P. Majors of the La Jolla Laboratory, and Forrest R. Miller, Meteorologist with the Inter-American Tropical Tuna Commission in Administrative Report LJ-87-00, "Summary of the 1986 North Pacific albacore fishery data." More than 375 copies of these reports will be distributed to participating fishermen in June, 1987. Another 400 reports will be sent to state fisheries agencies to be distributed at the waterfront by samplers during the 1987 albacore fishing season. Copies can be obtained upon request to the Director, Southwest Fisheries Center.

Atlas of the United States North Pacific Albacore Fishery, 1961-1980

An atlas has been prepared by Fishery Biologist Anthony Majors titled, "United States North Pacific albacore fishery, 1961-1980," which presents charts and tables that summarize the fishing effort, catch, size composition of fish sampled and catch distribution of the albacore (Thunnus alalunga), caught by the U.S. North Pacific albacore fishing fleet from 1961 to 1980.

This information was obtained from logbooks maintained by fishermen and from interviews with fishermen conducted by state biologists from California, Hawaii, Oregon, and Washington at landing sites during the albacore fishing season. Biologists also measured and collected length-frequency data on the landings.

During this 20-year period, more than 53% of the total catch was landed in different ports throughout California, 34% in Oregon, 12% in Washington, and less than 1% in Hawaii. Approximately 79% of the sampled vessels fishing for albacore in the North Pacific used jigs, 12% used bait, and 9% used either a combination of bait and jigs or other types of gear. Effort and catch sampling coverage (sampled landings/total landings) for 1961 to 1980 averaged 28.6%; length-frequency sampling coverage (measured fish/total landings) averaged 0.7%. Also, during this same period, a seasonal average of 833 vessel landings was sampled for fishing effort and catch, either from logbooks or through personal interviews with fishermen.

The atlas is in press as a NOAA Technical Memorandum, and will be available from the National Technical Information Service, 5285 Pt. Royal Road, Springfield, Virginia 22167.

Albacore Model Implemented; Encompasses Large Set of Parameters

An albacore model that simulates recruitment, growth, movement, natural mortality, and harvest of albacore by three fishing fleets, the Japanese baitboat fleet, the Japanese longline fleet, and the U.S. jig fleet, has been developed by Fishery Biologist Pierre Kleiber at the Southwest Fisheries Center in La Jolla. The model begins with starting values of the population of fish at large and the disposition of those fish both geographically and by each fleet as a function of time and geographic area on the basis of a time series of effort values by fleet and geographic area and a large set of parameters of recruitment, growth, movement, natural mortality, and harvest.

The purpose of the model is to provide a tool for evaluating the possible effects of various management actions on the fishery. It has not, however, so far been used for this purpose since restrictive management schemes have not been proposed for the North Pacific albacore fisheries.

Instead, Kleiber has used the model to investigate interaction between fishing fleets, an issue which is of interest to fishermen and fishery managers. The requirements of the model are similar to those of evaluating management actions. A typical year in the life of the fishery was produced by simulation over many years, with the input of constant recruitment and a constant seasonal pattern of fishing effort. Thus, the results were not dependent on precise starting values. The nominal catch of each of the fleets in the typical year was compared with catch when the effort in one of the fleets was either doubled or halved. The results are sensitive to the exploitation rate, which in the model was adjusted to be in line with results of albacore tagging carried out for many years past in the North Pacific by the American Fishermen's Research Foundation, in cooperation with the Michael Laurs and scientists of the Southwest Fisheries Center.

Kleiber's modeling effort has also served as a focus for planning albacore research by identifying gaps in what is known about albacore. In addition, plans are underway to use the model as a basis for developing two new methods of data analysis, both taking advantage of the built-in geographic structure and migration features of the model. One would be a geographically heterogeneous form of cohort analysis and the other would be a quantitative evaluation of migration from tagging data.

Study on Relationship Between Albacore Distribution and Environment Underway

At the Pacific Fisheries Environmental Group at Monterey, California, Fishery Biologist Richard Parrish is leading a project to study the relationships which may exist between the spatial distributions of albacore and environmental phenomena in the North Pacific.

To determine these relationships Parrish is statistically comparing a number of environmental data bases which have been developed for different regions of the North Pacific, and a voluminous collection of age-specific fishery data, featuring high temporal and spatial resolution, from a study recently completed by Earl Weber of the La Jolla Laboratory. The object of this research is to determine how large scale environmental fluctuations affect the apparent abundance of albacore throughout the North Pacific with emphasis on understanding the fluctuations in the abundance of albacore experienced by fishermen along the West Coast of North America.

Parrish is also supervising an effort to document the current understanding of albacore biology in the North Pacific. This documentation, which involves scientists from throughout the Southwest Fisheries Center, will emphasize the results of analyses conducted in accordance with the Center's Strategic Plan for North Pacific Albacore (Parrish, et al., 1985, NOAA-TM-NMFS-SWFC-52). The document is scheduled for completion in the fall of 1987.

Joint NMFS/Albacore Fishing Industry Tagging Program

A cooperative North Pacific albacore tagging program was initiated in 1971 between the Southwest Fisheries Center's La Jolla Laboratory and the American Fisherman's Research Foundation (AFRF), an industry organization made up of albacore fishermen and processors. Initially, SWFC fishery technicians conducted most of the tagging operations onboard albacore fishing vessels that had been chartered by AFRF for research and scouting operations. However, for about the past 12 years, virtually all the tagging has been done by the fishermen themselves. Management of the cooperative program is provided by the La Jolla Laboratory under the direction of Oceanographer Michael Laurs.

The La Jolla Laboratory maintains a computer data base of the data recorded for all the fish that have been released and for those recovered during the joint program. Scientists are using the base for research, data analyses and reports of tagging results which are provided as feedback to the industry and for conducting training of fishermen in tagging methods. The tagging equipment is provided by the SWFC, which also distributes a baseball cap with an albacore tagging logo to all the fishermen who conduct the tagging and release operations and to those who report recovering tagged albacore. AFRF pays the major costs for operating the program, including reimbursement to fishermen for fish tagged and released and payment of rewards in a special lottery for tagged fish that have been recovered.

Approximately 24,000 albacore have been tagged and released and about 1,400 tagged fish have been recovered in the North Pacific. The computer data base of release and recovery data collected during the joint program was recently augmented to include all historical records that are available for North Pacific albacore tagging that were conducted by various U.S. and Japanese agencies.

The cooperative tagging program was extended to include South Pacific albacore in 1986 as part of the U. S. albacore fishery exploration and research underway in the South Pacific. Approximately 1,500 South Pacific albacore have been tagged and released by fishermen, in addition to about 1,000 that have been tagged and released by SWFC scientists on the NOAA ship Cromwell and fishery scientists from New Zealand and French Polynesia.

The joint government/albacore industry tagging program has provided significant new information about the North Pacific albacore resource. For example, the tagging data have been used to determine North Pacific albacore age and growth rates, to investigate migration patterns and stock structure, to provide information needed to develop the "albacore model", and to plan fishery exploration studies that have extended the range and time that the U. S. albacore fishery operates.

Albacore Fishery Advisory Operations

The La Jolla Laboratory continued to provide albacore fishery advisory information during 1986. The advisory operations are part of a quid pro quo arrangement whereby fishermen receive information in return for voluntarily providing logbook records, making oceanographic observations, participating in the joint albacore tagging program described above and related activities. The advisory information distributed this past year included the seasonal forcast for the U. S. North Pacific fishery prepared by Michael Laurs and his staff, biweekly albacore fishery bulletins and daily albacore broadcasts, prepared by Fishery Biologists Ron Dotson and Bob Nishimoto and issued during the season. This is the 26th year that the La Jolla Laboratory has issued the albacore advisory.

Forecasting Model for Albacore

Fisheries scientists have long been interested in being able to forecast when, where, and how many fish will occur in a fishery. The ability to forecast for the albacore fishery is especially important because the cost of search time to the fleet is high and there is a long history of research on the factors influencing albacore distribution, much of it done at the Southwest Fisheries Center. Roy Mendelssohn, Operations Research Analyst and Oceanographer David Husby of the Pacific Fisheries Environmental Group (PFEG) have been working on a fine-scale quantitative forecasting model of the albacore fishery off the west coast of the United States.

Currently, they are analyzing the northeast Pacific albacore logbook catch data and corresponding environmental data (wind, sea surface temperature) for evaluating the feasiblity of developing an environmental-dependent causative model of 2-week temporal resolution and one-degree latitude/longitude spatial resolution. In constructing the model they are developing new analytical methods, including the development of empirical methods for identifying the form of nonlinear relationships. They hope to improve the ability to interpret catch data as indicators of population abundance and the ability to forecast locations of high probability of fishing success 2 weeks in advance.

SOUTH PACIFIC ALBACORE

Although albacore tuna are abundant in the South Pacific, most of the annual catch of 35,000 tons is harvested in subtropical waters at depths of 450-750 feet by tuna longline fleets from Taiwan, South Korea, and Japan. Only a few thousand tons are caught near the surface, mostly by small New Zealand trollers fishing near their home islands.

In January of 1986, two U.S. trollers, partially supported by Saltonstall-Kennedy funds, ventured into the South Pacific for the first time and made excellent catches at the surface in an area about 1,200 square miles. In 1987, the boats returned to the same location and were joined by 6 other trollers, all of whom made phenomenal catches of up to 10 tons of albacore per day. The development of the South Pacific fishery is a welcome upturn of fortune for the U.S. albacore fleet which has been plagued with dwindling catch rates and market opportunities in the North Pacific.

The success of these boats has led to a collaborative effort among the SWFC in collaboration with the U.S. albacore industry, the New Zealand Ministry of Agriculture and Fisheries, the French agency ORSTOM, and the South Pacific Commission. With scientists from the Honolulu Laboratory taking the lead, the program is directed at a range of areas including fishery data collection, stock assessment, biology, and fishery development. The objectives are to estimate the potential yield of a surface fishery, to compute the impacts of a surface fishery on traditional longline operations, to understand albacore population dynamics, and to model the relationship between albacore distribution and availability, and such oceanographic features as currents and thermohaline structure.

Workshop on Research Planning

In June 1986, SWFC scientists attended a Workshop on South Pacific Albacore Research (SPAR) hosted by the Fisheries Research Division of the New Zealand Ministry of Agriculture and Fisheries and sponsored by the South Pacific Commission. The participants agreed to exchange data on albacore fisheries and develop a coordinated research plan to improve stock assessment capabilities. They also agreed to collaborate in a joint program of tagging South Pacific albacore for the purpose of delineating movement patterns of the albacore (the South Pacific Commission was to manage the tag data base) and to coordinate research cruises.

Townsend Cromwell Survey

One result of the SPAR was a coordinated joint survey of albacore in a band of water called the Subtropical Convergence Zone (STCZ) extending from Chile to New Zealand about 2,400 miles south of the Equator. The Convergence is an area where subtropical and subantarctic waters blend together. Fishermen and biologists have found that this is where many kinds of open ocean fishes are especially abundant.

The ORSTOM vessel, Coriolis, operated between 120°W and 135 °W, the NOAA Ship Townsend Cromwell between 149°W and 165°W, and the New Zealand research vessel, Kaharoa, between 170°W and the New Zealand coastal waters. These joint surveys were designed to

provide the first comprehensive description of near-surface oceanography in the STCZ together with an assessment of the distribution and availability of albacore to surface trolling.

Jerry Wetherall of the Honolulu Laboratory was the Chief Scientist on the Cromwell, where he was joined by Christofer Boggs, Victor Honda and Shigeru Yano, also of the Honolulu Laboratory, Kenneth Bliss and Michael Laurs of the La Jolla Laboratory, Kevin Bailey of New Zealand, Ned Howard of the Cook Islands and Viliami Langi of the Kingdom of Tonga. Participation of the latter two scientists was arranged and financed by the South Pacific Commission.

During the Cromwell survey, transect placement and the location of "albacore water" in the region was assisted greatly by the sea surface temperature imagery received from NOAA polar-orbiting satellites equipped with infrared sensors. Images were received on the Cromwell in real-time and enhanced using the JCV-16E Oceanographic Color Display which was loaned to the Honolulu Laboratory by the Japan Radio Co.

At over 100 locations in this zone the research vessels lowered special instruments to depths of over 3,000 feet to measure vertical and horizontal changes in ocean temperature and salinity. This information was collected for use in describing the physical characteristics of the convergence and particularly the areas near the ocean surface considered optimum for albacore trolling. In these areas albacore concentrate to feed on small mackerel and other animals such as squid and amphipods.

The research ships and commercial boats also caught, tagged and released alive about 800 albacore. The hope is that these fish will be caught again by fishermen and the tags or both tag and fish returned. A reward will be offered for return of the tagged fish. Recapture information will provide valuable information on the migration habits of South Pacific albacore about which virtually nothing is known.

In addition to the oceanographic mapping and albacore tagging, the research vessels collected biological material for estimating the ages and growth rate of albacore and for determining their geographical origins, maturity, fat levels, and food habits.

The data collected during the surveys and commercial fishing operations will be shared among researchers and fishing interests in the participating countries and used as a basis for understanding the distribution, availability and abundance of this little-known resource in the South Pacific.

Future Work

During this fiscal year, a joint strategic research plan will be completed for South Pacific albacore research by the

Honolulu Laboratory. The plan will focus on specific programs to achieve the objectives of better stock assessment and efficient fishery development. In the coming years steps will be taken to improve the fishery data base, estimate the overall potential yield of the resource and assess the impacts of a developing surface fishery on the traditional longline operations of Taiwan, Korea, Japan, and South Pacific nations. Critical aspects of biological and oceanographic research will be identified and programs developed to address them. Emphasis will be placed on continued cooperation with the U.S. industry in tagging albacore and collecting information on albacore biology and environment.

South Pacific Fishery Exploration/Research Reports

Michael Laurs, in collaboration with Jerry Wetherall at the Honolulu Laboratory and Ken Bliss at the La Jolla Laboratory prepared two reports dealing with the South Pacific albacore fishery exploration/research operations conducted in 1986. One of the reports gives details on the albacore catches and research operations conducted by the two U. S. albacore troll fishing vessels that participated in the study, and the other documents the fishery and research findings made by the R/V Cromwell. Both reports are available from the Southwest Fisheries Center in La Jolla.

IN SUPPORT OF

DOMESTIC REQUIREMENTS

GOALS DEVELOPED FOR SWFC TUNA PROGRAM

In early 1986, Joseph W. Angelovic, Deputy Assistant Administrator for Science and Technology made a decision to divide responsibility for tuna and billfish research in NMFS. In his memo he directed that the Southeast Fisheries Center will be responsible for all NMFS research to support the International Commission for the Conservation of Atlantic Tunas. The Southwest Fisheries Center will be responsible for all NMFS research for the Indian Ocean, Western and Central Pacific and any Federal efforts associated with the Eastern Tropical Pacific.

During the past year, in recognition of these changed responsibilities, Director Barrett and program managers at the Southwest Fisheries Center met to discuss the overall objectives of SWFC tuna research and to identify issues related to these goals that required resolution. With the advice and concurrence of SW Regional Director Charlie Fullerton, the managers agreed on the four following goals for a SWFC tuna program.

- To establish and operate a tuna data collection and intelligence system to provide quantitative data for NMFS research and management and assist the U.S. tuna industry to be more competitive internationally.

The managers noted the importance of coordinating collection of data and maintaining a central tuna data base so that researchers can perform analyses required in agency decisions.

- To produce information on the status of stocks of tuna fisheries and on Pacific and Indian Ocean tuna and billfishes.

For this goal, Barrett emphasized the need for timely assessments of stock condition of interest to the U.S., particularly with respect to recent developments in the Indian Ocean and western Pacific.

- Acquire new information through research to improve the conservation of the resource or the prosecution of the fishery.

The managers agreed that research on assessment methodology and techniques should be an integral part of the other goals. Better tools and ways to conduct an accurate stock assessment are in short supply. Barrett stated that this goal is to develop better assessment methods and techniques through research.

- Provide to NMFS managers the best possible descriptions of feasible alternatives for developing U.S. strategy for fishing and managing the Pacific and Indian Ocean tuna fisheries, together with the best quantitative and qualitative estimates of the biological, environmental, economic-social and political impacts of each alternative.

In regard to the above goal, Barrett noted the need for an examination of U.S. policy and formulation of long-range strategic plans that could guide the development of U.S. tuna fisheries and possible international management in the western Pacific and Indian Oceans.

The steps to implement this program have been taken with the assignment of Gary Sakagawa as Program Coordinator and the preparation of operational plans for each of the goals.

STATUS OF HAWAII SKIPJACK FISHERY ASSESSED

The Honolulu Laboratory organized a series of meetings in 1986 to evaluate the status of Hawaii's aku (skipjack tuna) fishery and seek remedial measures to a host of problems in the industry. The meetings brought together fishermen, scientists, state and federal government fishery officials and legislators.

Aku Workshop Reviews Plight of Industry

The first meeting was a workshop entitled "Forces of Change in Hawaii's Aku Industry," held on April 30 and May 1, 1986 at the former Hawaiian Tuna Packers cannery in Honolulu. In a series of papers, oral presentations and open discussions participants from industry, government, universities and research organizations reviewed the status of Hawaii's aku industry on the basis of biological and economic analyses and practical experience.

The aku industry was once the leading supplier of seafood in Hawaii. Aku set the price standard for the fresh fish market and supplied about 20% of the Hawaiian Tuna Packers pack. During the last decade the annual aku catch dropped to about half of its long term average of 4,000 metric tons. The number of commercial pole-and-line boats dropped from 15 in 1971 to 9 in 1986. Annual revenue decreased by about $2.7 million between 1974 and 1982. In 1984 the HTP cannery, which had absorbed most of the annual harvest, closed.

At the workshop, marketing problems, increased operating costs, rising insurance costs, declining fishing efficiency, and declining abundance or availability of large-sized aku were identified either as causes or as possible contributing factors to the industry's decline. Economic projections suggest that without an expanded market, the aku fleet will be reduced to 4 or 5 of the most efficient vessels which will supply annually about half of the 2,000 mt local market for fresh aku. The rest will be imported.

Corrective Actions Identified

Following the aku fishery workshop, a strategic planning meeting was organized by the Honolulu Laboratory to assist in identifying remedial measures for rejuvenating the aku industry. The planning session, using an interactive management technique, was held on June 27-28 at the Honolulu Laboratory and co-sponsored by the State of Hawaii Division of Aquatic Resources, the Tuna Boat Owner's Co-op, Inc., the United Fishing Agency, Ltd., the University of Hawaii Sea Grant College Program and the Western Pacific Regional Fishery Management Council. Planners included members of industry, academia, state and government agencies and the Hawaii State Legislature.

The group identified many activities which could help revive the aku industry, including market studies, new procedures for handling and distributing the catch and various actions to cope with supply fluctuation in the absence of the cannery. The group emphasized that the industry itself must become more involved in recovery efforts.

A report of the group's findings and recommendations was prepared by the Honolulu Laboratory, distributed to industry members and presented to the Hawaii Fisheries Coordinating Council. This report is available from NMFS as Administrative Report H-87-1. Background information presented at the aku workshop is available in Administrative Reports H-86-11C, 12C, 13C and 14. A comprehensive proceedings of the workshop has been published as NMFS Technical Memorandum NOAA-TM-NMFS-SWFC-72.

BILLFISH RESEARCH

Pacific Cooperative Marine Gamefish Tagging

Under the auspices of the Cooperative Marine Gamefish Tagging Program, U.S. and foreign recreational fishermen have tagged billfish to help fishery scientists determine the migration patterns and geographic limits of the populations of gamefish in the Pacific Ocean. The tagging program, which began in the Pacific in 1963, is currently supported by the National Marine Fisheries Service in cooperation with the International Gamefish Association and the Gardiner Foundation. During the past several years, additional support for the tagging program has been contributed by the National Coalition for Marine Conservation. James Squire, Fishery Biologist at the SWFC laboratory in La Jolla, California, coordinates the Pacific program, as he has since its inception.

Cooperative Marine Gamefish Tagging Program, 1986

In 1986, anglers tagged and released a total of 1,252 fish of all species, an increase of 413 fish over 1985. This number

represents the number of tag cards returned to the Southwest Fisheries Center from January 1 through December 31, 1986. Of these, 1,203 were billfish; in 1985 a total of 653 billfish were tagged and released. Tagging of striped marlin in southern California, as well as total catch, was down substantially; 59 billfish were tagged and released, compared with 217 in 1985.

Squire noted that in 1986 19 recoveries were recorded. Of these 5 or 26% did not have a tag card, which he considered a poor record. A substantial number of anglers, it seems, are not returning their tag cards after tagging the fish. The rate of tag recovery for billfish is low (1% to 3%) and every tag recovery counts substantially toward increasing the understanding of billfish migrations throughout the world's oceans.

Of the 19 tags recovered and returned to the Southwest Fisheries Center in 1986, 9 were striped marlin, 2 were blue marlin, 1 was a black marlin and one was a sailfish. Several long distance recoveries were made. The most notable recovery was a blue marlin tagged off Christmas Island on October 21, 1985 and recovered off New South Wales, Australia. This fish traveled 3,420 nautical miles (straight line) distance in 136 days. Another long distance recovery was a blue marlin tagged off the Coronado Islands, Mexico (near San Diego, California). This fish was recovered 340 days later after it had traveled 690 nautical miles south.

The tagging has shown interesting migrations in striped marlin tagged in the same general area. For example, a striped marlin was tagged off southern California near Santa Rosa Island on September 7, 1984. The fish was recovered by a Japanese longliner north of the Hawaiian Islands, 2,460 nautical miles west and 636 days later. In contrast, a striped marlin which had been tagged in the same general area off southern California two days earlier (on September 5, 1984), was recovered off the southern tip of Baja, California, Mexico by a commercial longliner, 20 nautical miles south and 807 days later.

Studies on Billfish Behavior and Interaction

A continuing research study between the staff of the La Jolla Laboratory and scientists from the California Department of Fish and Game was successful in tracking two striped marlin and one swordfish during the past year. These studies are designed, in part, to gain additional information on the local availability of billfish in the area and to determine their vulnerability to various types of commercial and recreational fishing gears.

According to Fishery Biologists David Holts and Earl Weber and CF&G Biologist Dennis Bedford who participated in six, one-week observation trips in the Los Angeles Bight aboard a 60-foot sport fishing vessel chartered by the State for these studies, sonic tagging and tracking of these large pelagic fish is useful in identification of their habitat preference and will allow more

direct and efficient placement of fishing gear. Accurate knowledge of vertical and horizontal swimming patterns, the distribution of swimming speeds and temperature (depth) preferences are also important in developing models on growth and energy budgets for the large billfishes.

The first striped marlin was caught and tagged just after noon on September 27, 1986, 6 miles east of Avalon, Santa Catalina Island. The vertical and horizontal movements of this fish were tracked over a 24-hour period. The animal traveled generally south for 37 nm at an average speed of 1.5 knots; it spent 63% of the time at or above 12 m, 36% of the time between 12 and 40 m, with only four short descents below 40 m.

The second marlin was tagged near the west end of San Clemente Island and tracked for only 3 hours when the signal was lost due to a damaged hydrophone wire. This second marlin traveled 5.5 nm in a southerly direction and stayed very near the surface during the tracking period.

These observations match closely the results of another tracking of a striped marlin conducted in 1982 by Holts and Weber. This fish traveled north for 4 hours, remained relatively inactive in the evening hours and then proceeded west for the next 17 hours. While traveling an average of 1.5 kts, the fish covered a total distance of 18 nm. Nearly 86% of the tracking time was spent in the top 10 m of the water. It made only five short, early morning descents below 30 m. These vertical and horizontal observations of the behavior of striped marlin are in sharp contrast to the movements of the swordfish.

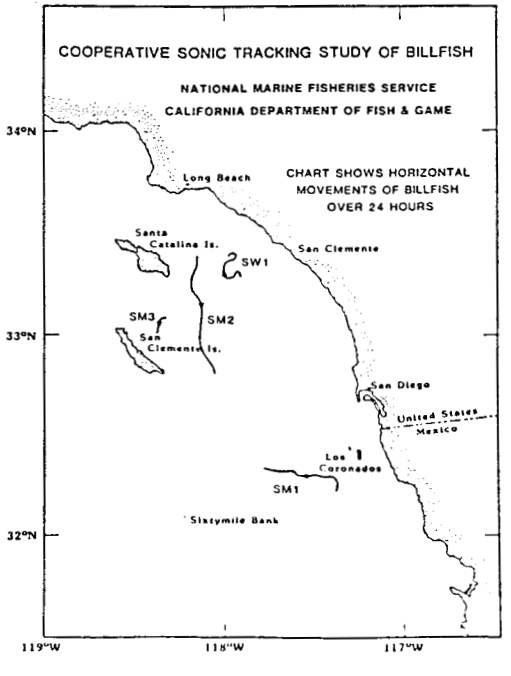
The swordfish was tagged by a commercial harpoon fisherman, midway between Avalon and Dana Point, California. This broadbill traveled in a broad, clock-wise circle that covered about 17 nm and ended 8 nm northwest of the location where it was tagged. This fish spent essentially all of the time below 10 m and descended below 320 m on two different occasions. During each of these descents, the swordfish went from 45 m to over 320 m in less than 15 minutes. This constitutes a change in ambient pressure from 80 psi to over 570 psi, and temperature change from 14 degrees C to 8 degrees C. the first deep dive occurred in the late afternoon and lasted about 90 minutes. The second dive started at 0845 hours the following morning and lasted just over 3 hours. This particular dive occurred at the 14-fathom spot, a small bank reaching to within 57 fathoms of the surface. Here the forward progress of the fish decreased and it appeared to be foraging at or very close to the bottom.

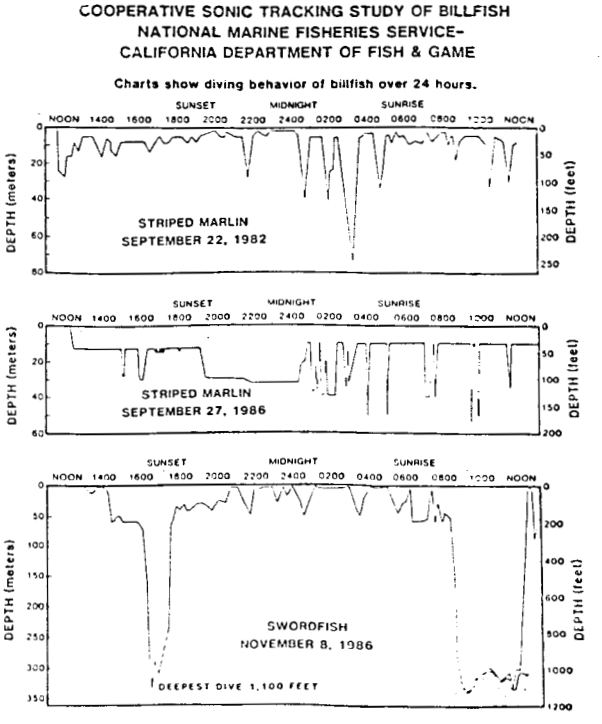
Preliminary results of this work indicate that the diel behaviors of the two species of billfish differ greatly. The tracks suggest that swordfish and striped marlin spend 100% of the night hours at depths between 10 m and 50 m. the striped marlin spent 60 to 90% of their time between 10 and 30 m deep, but did not go below 60 m. Vertical excursions were more numerous at night but also occurred at irregular intervals

throughout the tracking period. The swordfish spent considerable time (1.5 and 3.5 hours) at depths over 1000 feet. Both dives were marked by abrupt descent (and ascents) which is remarkable considering the tremendous physiological stress on the fish from changes in water temperature and pressure. The swordfish appeared to be orienting to the shallow bank where its second deep dive occurred. Marlin tended to swim faster and in a more continuous direction. The extent of their vertical excursions, for the most part, were limited to the dark period between midnight and first light. This was also the period of least horizontal movement.

Several elements of their behavior were similar to other pelagic species as well. As with several species of tuna, billfish show no reluctance to descend into the colder waters below the thermocline. In two separate dives, the swordfish tracked spent 19% of its time in very cold water. At night, tuna generally shift their modal depth to the layers nearer the surface; these billfish showed no obvious sign of this behavior. The vertical excursions of marlin tended to be greater between midnight and sunset but swordfish indicated no increased activity during this period. Marlin covered a greater horizontal distance and maintained a steady depth over longer periods than did the swordfish. Biologists have suggested some tuna species reduce the frequency of vertical excursions during periods of migration.

During this study, three fish were tagged in 30 boat days. This clearly indicates the difficulty in catching and successfully tagging billfish in southern California waters where they only occur seasonally and are never very abundant. Plans are to continue this cooperative program through next year in order to obtain additional tracks of the movements of both species of billfish. Final results of this study will be released at the end of the 1987 season.





TUNA/PORPOISE RESEARCH

Trend in ETP Dolphin Abundance

Since the passage of the Marine Mammal Protection Act (MMPA) in 1972, the United States has been committed to long-term management and research programs to conserve and protect these animals. In implementation of the MMPA, the Southwest Fisheries Center staff conducts a program of research which is directed toward understanding the abundance and biology of dolphins associated with the purse seine fishery for tunas in the eastern Pacific. In 1986, research efforts continued to concentrate on questions concerning changing abundance of the dolphin stocks, stock structure, and distribution, biological profiles of the animals killed, and the rate at which these animals are replaced through new births.

In its 1984 reauthorization of the MMPA, Congress called for an expanded stock monitoring program to monitor trends in the abundance of stocks of dolphins killed incidental to fishing operations by the U.S. purse seine fishery for tropical tunas in the eastern tropical Pacific Ocean. It was the intent of Congress that this mandated monitoring program last at least 5 years, after which the status of dolphin stocks in the ETP will be reviewed.

First Cruises of a Five-Year Program to Monitor Dolphin Abundance Completed

In implementation of this legislation, the Southwest Fisheries Center has initiated a monitoring program that uses data collected by observers on two very different platforms--research vessels, and U.S. tuna boats. Surveys using research vessels have been designed to detect an annual change in relative abundance of 5% per year for spotted dolphins. The experimental design involves two vessels transecting the study area for 120 days per year for a minimum of 5 years.

The first cruises of a 5-year program to monitor the abundance of dolphin stocks in the eastern tropical Pacific have been completed, and the scientific observers aboard the two NOAA Ships, the David Starr Jordan and the McArthur returned to San Diego in early December, 1986 after almost 5 months at sea. Operations research analyst Rennie Holt was the chief scientist for the surveys and fishery biologist Wesley Parks the logistics coordinator.

The monitoring program is the result of an amendment to the Marine Mammal Protection Act, which directed NMFS to design and carry out the program. The purpose is to determine if the tuna purse seine fishery in the eastern tropical Pacific has adversely affected one or more of the dolphin stocks that are associated with the schools of tuna that are fished.

Twelve scientific observers spent their days searching for schools of dolphins. They recorded how many animals they saw, the species of the animals, and where the animals were sighted. This information was subsequently edited and entered on the data base.

From preliminary summaries of the data, the two vessels traveled approximately 43,000 nautical miles (nm). The Jordan traversed about 21,800 nm and the McArthur traveled about 21,300 nm. Within the study area, about 15,000, 11,000, 6,000, and 6,000 nm were covered in the inside, middle, west and south areas, respectively. During the surveys, 1,142 marine mammal schools, consisting of 59,235 animals were detected. Observers aboard the Jordan saw 765 schools consisting of 31,136 animals, and 377 schools consisting of 28,099 animals were detected from the McArthur. It was more difficult to detect marine mammals from the McArthur, which experienced rougher weather, than from the Jordan. However, the McArthur, covered the south and west areas, which probably have a lower dolphin density.

In conjunction with the dolphin sighting surveys, scientists also conducted research aimed at better defining the oceanographic "habitat" occupied by cetaceans in the ETP, and how changes in the environment affect the dolphin assessments. For example, there appear to be important changes in dolphin distribution in the ETP during a major El Niño, similar to the one which occurred in 1982-83.

The dolphin habitat research is being coordinated by Steve Reilly, Fishery Biologist. The habitat data also contribute to major national and international oceanographic studies: the Eastern Pacific Ocean Climate Study (EPOCS) and the Tropical Ocean Global Atmosphere program (TOGA). Also collaborating with Center scientists in the environmental research were scientists from NOAA-ERL's Atlantic Oceanographic and Meteorologial Laboratory (AOML), the Duke University Marine Laboratory, U.C. Santa Cruz, Scripps Institution of Oceanography, and the Smithsonian Tropical Research Institution.

While the ships were underway, data were recorded continuously on surface temperature, salinity, and fluorescence (as an index of phytoplankton). Expendable bathythermographs (XBTs) were deployed six times a day on the average. At dawn and dusk, the ships stopped for about an hour to conduct oceanographic stations at which vertical conductivity-temperature-depth measurements were made by lowering a CTD instrument to 1,000 m. Sample bottles attached to the CTD collected sea water at various depths to verify the instrument data, and to obtain vertical profiles of nutrients and fluorescence. In all 345 CTD stations were conducted and 1,145 XBTs were deployed.

Study Underway to Assess Utility of Tuna-Vessel Observer Data for Determining Long-Term Trends in Dolphin Abundance

In answer to such questions as, "How do tuna vessels search for dolphin, how do they find them, and how do the data that observers collect on these boats relate to the true distribution and abundance of dolphin?", Elizabeth Vetter, Operations Analyst at the Southwest Fisheries Center in La Jolla, has begun developing two models: a spatially distributed, dynamic simulation model of the tuna-dolphin system in the eastern tropical Pacific (an environmental model), and a tuna-fishing system model, which will be superimposed on the environmental model. The answers to these questions are important in determining the trends in abundance of dolphin population involved in the tuna purse-seine fishery in the eastern tropical Pacific.

To determine trends in abundance, biologists working in the dolphin monitoring program use three kinds of data: abundance indices collected during research surveys, abundance indices collected by observers on U.S. tuna vessels, and estimates of population parameters such as birth rates, sex ratio, and age structure.

The research surveys are an expensive method for indexing abundance. A popular suggestion to reduce costs has been to ask tuna-vessel observers to collect the same sort of information previously collected by the research vessels. Certainly the potential for using data collected from these vessels to index population trends appears great because tuna vessels far exceed research vessels both in number and area covered during a trip. The problem with using data from tuna vessels, however, is that existing methods and theory for deriving estimates of abundance or trends in abundance depends strongly on the assumption that the data were collected in a random manner. This led to the questions on how tuna vessels search for dolphin, how they find them, and how the data that observers on these boats collect relate to the true distribution and abundance of dolphin.

The direct approach to answering these questions is to run research surveys, which would be designed to search randomly, concurrently, in both space and time, with normal fishing operations by the tuna fleet. Even in small lakes, such an endeavor would be extremely complex and expensive; in a system as large as the eastern tropical Pacific Ocean, it may very well be impossible.

An alternative is provided by the method of system simulation and analysis. This involves developing mathematical models that simulate the dynamics of the relevant state variables (in this case, dolphins, tuna, observers, and fishermen) and the processes that control these dynamics (such as oceanographic conditions and the price of tuna), then "collecting" data from the simulated system just as one would from the real system. In

this case, simulated observers would be "sent" aboard some subset of the vessels in the simulated tuna fleet; during their cruise they would "collect" the same type of data as real observers. The data collected from the simulated fishery are then analyzed by whatever methods have been proposed for the data from the real fishery, and estimates made of dolphin abundance, or trends.

Unlike the case for the real fishery (without concurrent research cruises), in the simulated system both bias and precision can be tested. One not only has the estimates derived from the (imperfect but realistic) sampling of the simulated tuna fleet, but also (because one has the underlying systems models), the "true" abundance and distribution of dolphins. A primary advantage of the approach is that it becomes possible to test relatively efficiently many more alternative methods under many different hypotheses about fleet configuration, oceanographic conditions, dolphin and tuna distribution and abundance, and economic constraints. Basically, it offers a cost-effective procedure for eliminating inappropriate analyses. Methods that do not work for the (by necessity less complex than the real thing) simulation models have little hope of being effective in the real world.

Tuna/Dolphin Observer Data Maintained

Data pertaining to dolphins associated with the tuna purse seine fishery have been collected by observers for the past two decades. The Staff at the La Jolla Laboratory is responsible for the maintenance of these data bases.

Recently, a thcrough cross-referencing edit of four major data bases for 1978 through 1984 was completed by Biological Technician Randy Rasmussen. Also completed was the standardized reformatting of all marine mammal effort and sightings for the period, 1971-1986. Another large task which has now been completed is the microfilming of the observers' original data collection forms. All forms, except life history information, are now on microfilm, 1971 to 1975 and 1978 to 1984, inclusive.

1986 Dolphin Quota Monitored

Under the direction of the NMFS Southwest Region, 40 tuna/porpoise observer cruises were fielded aboard U.S. flag commercial tuna purse seine vessels in 1986 for the ETP fishery. Twenty of these observed cruises were supervised by the Inter-American Tropical Tuna Commission (IATTC) and 20 by the National Marine Fisheries Service, Southwest Region. These cruises were used to monitor the numbers of dolphins killed by the U.S. fleet. In 1986, the dolphin mortality quota was reached with an estimated mortality of 20,692 animals, and further fishing for tuna associated with dolphins was prohibited effective October 21, 1986. The closure continued throughout the remainder of the calendar year 1986.

Tuna seiner operator's workshops were held for 14 tuna boat captains in 1986. A total of 81 operator and 34 vessel Certificates of Inclusion were issued. Net and gear inspections to ensure the presence of required dolphin safety gear were completed for 12 vessels that were available in port. Additional, 18 preliminary inspections conducted by observers at sea were returned.

Chapter on Seabird Relationships to Tropical Tuna and Dolphins Prepared

Fishery Biologist David Au and Biologist Robert Pitman of the La Jolla Laboratory have written a chapter entitled, "Seabird relationships to tropical tuna and dolphins," for inclusion in a book called "Seabirds and other marine vertebrates: Commensalism, competition, and predation." The book which will be published by the Columbia University Press describes seabird interactions with fish and marine mammals and fishermen in various seas of the world and from an evolutionary perspective.

Au and Pitman summarize their observations of the interactions between seabirds and yellowfin and skipjack tunas and with 17 species or species groups of cetaceans in the eastern tropical Pacific. They describe two distinct faunal communities: in one community bird flocks co-occur with yellowfin tuna and dolphins, and in the other, flocks co-occur with skipjack or other small tuna, but not with dolphins. They describe the species makeup of the flocks with dolphins (about 75% were spotted and spinner) and they show that this seabird-dolphin association is linked through the yellowfin tuna and a feeding aggregation. Au and Pitman present a hypothesis that explains the bird-tuna-dolphin association as an interaction of feeding tactics required to exploit certain configurations of prey.

Changes in Sex Ratio of Spotted Dolphins Correlated with Changes in Fishing Effort

At the Southwest Fisheries Center in La Jolla, Fishery Biologists Aleta Hohn and Susan Chivers have examined the sex ratio (number of females per male) across different age and reproductive classes. The sample includes 1,551 fetuses, 1,826 calves (animals smaller than 130 cm or approximately 1 year of age and younger), 2,257 juveniles (animals greater than or equal to 130 cm but less than or equal to 160 cm, the length at which differential growth of males and females begins), 2,281 immatures (animals greater than 160 cm and not sexually mature), and 5,396 adults (animals greater than 160 cm and sexually mature). All of the samples were collected by observers aboard tuna vessels. Hohn and Chivers found that changes in the sex ratio of spotted dolphins from the eastern tropical Pacific were significantly correlated with changes in fishing effort.

Hohn and Chivers tested the effect of fishing effort by examining differences in sex ratio between areas of high, medium, and low fishing effort. Their results show significant differences in sex ratio for all age classes, except fetuses, at all three levels of effort.

Variability in sex ratios of mammals is common and, in fact, many terrestrial mammals exhibit sex ratios which fluctuate with population density. Although it is not yet possible to equate fishing effort with density for these dolphin populations, examination of terrestrial mammal species may be instructive. In general, sex ratios at birth are slightly in favor of males and thus males often predominate from conception through birth. This is what Hohn and Chivers observed in dolphins from all fishing areas. However, male mortality rates exceed those of females throughout life, so the sex ratio of adults frequently favors females. Species exhibiting this pattern are fur seals, elephant seals, rats, humans, as well as a number of ungulate species.

Clearly, mammals are able to invest selectively in their offspring. Increased preweaning investment in males has been observed in both red deer and elephant seals as well as other species. The increased preweaning investment is manifested as heavier birth weights, faster growth rates, and later weaning dates and result in sexually dimorphic adults. The ability to vary the sex ratio of offspring enables a female to respond to changing conditions in such a way as to maximize her reproductive success.

In addition to selective post-natal investment in female or male offspring, females of many species have been observed to produce males when they are in a "good condition" and females when they are in "poor condition." Females in good condition will produce the healthiest young and a healthy male will produce the most number of grandchildren, thus maximizing her reproductive potential. Conversely, production of female offspring results in the highest returns when conditions are less than adequate to produce a top quality male. Synonymous with poor condition, the term stress in the literature has most often been used to refer to nutritional stress, although it may also be used to describe behavioral and physiological conditions. Whatever the descriptor, stress or poor condition, the result in most animals is a sex ratio in which there are more females than males. Among ungulate species populations considered stressed are frequently those subjected to excessive mortality, predation and hunting, which may or may not be associated with nutritional stress. These populations exhibit a sex ratio favoring females at the time of birth.

The spotted dolphin population of the eastern tropical Pacific may be considered to be stressed. Although food may be plentiful because of reduced population levels, an element of stress must be induced by fishery activities. Sets on larger schools of dolphins are preferred by the tuna fishery because of the correspondingly larger number of tuna they are associated

with. The larger schools are also likely to be breeding schools and to contain a higher proportion of mature females. Fishing operations which include an initial and often extensive chase prior to encirclement must be disruptive because the operations interrupt foraging and other normal activities. Additionally, in heavily fished areas, females are likely to have been set on repeatedly, thus increasing the level of stress. Those areas fished for the longest time and with the greatest regularity exhibit a sex ratio most highly skewed in favor of females.

Thus, if information supplied by studies of a variety of mammalian species is applicable, Hohn and Chivers believe that general condition of the population may be inferred from the examination of sex ratios. Further evaluation must consider other reproductive and growth rate parameters, including body condition, annual pregnancy rate, lactation period, calving interval, and age at sexual maturation. In concert with examination of many life history traits and results from a 5-year research vessel survey monitoring changes in population levels, the results presented here may be applicable to monitoring trends in the population.

Handbook for Dolphin Sampling Completed

Recently completed by Al Myrick, Wildlife Biologist at the Southwest Fisheries Center in La Jolla, is a 69-page booklet for tuna-dolphin observers entitled, "Procedures for sampling dolphins: A handbook for shipboard observers." In this handbook Myrick discusses the proper use of sampling equipment, explains the procedure for taking, preserving, and storing biological samples, and describes the features and location of anatomical sites from which samples are taken. Descriptions of data and specimen collection are supported by the 22 figures in the handbook and an extensive index which provides ready reference to key-word topics.

Designed as more than a "how-to" manual, the objective is to help the shipboard observer understand the importance of the job and how the work is relevant to the research mission. For example, the handbook includes explanations of why particular procedures are required and how various samples will be used in ongoing biological studies. Although intended primarily as a presentation of sampling guidelines for the observer in training, it also contains information that the more experienced field scientist may find useful. The handbook has been published as NOAA Technical Memorandum, NOAA-TM-NMFS-SWFC-62.

TUNA BEHAVIOR AND PHYSIOLOGY

Ongoing Shoreside Experiments Concluded, New Work Put on Hold

Over the years the Honolulu Laboratory has earned a worldwide reputation for excellence in research on the physiology and behavioral ecology of tropical tunas. Research on metabolic rates and energetics of free swimming tunas, sensory biology, artificial spawning and larval development and environmental tolerances of tunas has been carried out by Honolulu Laboratory personnel, graduate students and visiting scientists at the Kewalo Basin Research Facility. Basic biological research of this nature is an essential part of an effective long term strategy to improve stock assessments and models of population dynamics. Realistic models of skipjack and yellowfin tuna dynamics must consider their high degree of mobility, their responses to environmental variation, and other factors which determine movements, availability and catchability.

Unfortunately, due to budget reductions basic physiological research was curtailed in FY 87. Effort was placed on completing a few studies already in progress and due to be finished by the end of 1987. After this fiscal year, work will be placed on hold until budgets cuts can be restored or outside funding sources found.

Possible Impacts of Parasite on Yellowfin Mortality Studied

One of the studies concluded by the Honolulu Laboratory in FY 87 was a study of the possible natural mortality effects of the intra-vascular larval cestode (i.e., tapeworm) parasite (Dasyrhynchus talismani) on yellowfin tuna (Thunnus albacares). Laboratory and field experiments were finished in FY 86, but the analysis of the results was completed this year. A manuscript describing the incidence of infection and effects of the larval cestode parasite was submitted for publication in Fishery Bulletin. The work was co-authored by Richard Brill, Robert Bourke, Jim Brock and Murray Dailey.

The parasite is found in the dorsal aorta (the major blood vessel supplying blood to the fish's swimming muscles and internal organs) of up to 60% of the small yellowfin tuna (1-3 kg body) caught near Hawaii. Because the parasite and resultant host inflammation often appear to almost totally occlude the dorsal aorta, the original hypothesis was that the parasite could be a significant factor in the natural mortality of this commercially important species. To test this hypothesis, fork length, body weight, liver weight, heart weight, RNA/DNA ratios (a measure of short term growth rates), and otolith weight (a measure of long term growth rate) were measured. No statistically significant differences were found between

parasitized and unparasitized fish. How yellowfin tuna are apparently able to remain unaffected by occlusion of their dorsal aortas could not be determined.

The incidence of infestation in small tuna caught between February 1985 and March 1986 and the incidence of dorsal aorta infestation in large (<45 kg) fish were also measured. Large yellowfin tuna were rarely parasitized (<5%) in the dorsal aorta but showed a high rate (<80%) of infestation in other major arteries. The higher incidence of parasites in the dorsal aorta of small yellowfin tuna varied dramatically with season. The infestation rate of small fish dropped suddenly from 66% in June-July 1985 to 11% in August-September 1985, most likely due to influx of a separate group of unparasitized fish into the Hawaiian fishery. Therefore, it appears that Dasyrhynchus talismani may serve as a marker for tracing the movements of small yellowfin tuna into and out of specific fisheries or areas.

Responses of Tuna to Low Ambient Oxygen Modeled

During FY 87 research was also concluded on the reactions of tunas to low ambient oxygen levels. The habitat, distribution, gear vulnerability and perhaps even natural mortality of tunas is partly determined by ambient oxygen levels. The objective of this project was to define skipjack and yellowfin tunas' reactions and tolerances to low ambient oxygen conditions as a basis for modeling tuna habitat and distribution. The research was conducted by Peter Bushnell, a graduate student in the Department of Physiology, University of Hawaii, and Fishery Biologist Richard Brill of the Honolulu Laboratory. Because the work involved simultaneously measuring ventilation volume, cardiac output, heart rate, and mouth gape the work had to be done on tabled (i.e., non-swimming), animals. To do this the investigators developed the new technique of spinally blocking (i.e., paralyzing) the fish by directly injecting the local anesthetic Lydocaine into the spinal column behind the head. This leaves the animal fully conscious and able to make natural physiological adjustments to imposed low ambient oxygen levels.

The study found that tuna are very sensitive to the level of oxygen in the water. When tuna are exposed to very mild reductions on ambient oxygen, well above lethal limits, compensatory cardio-respiratory adjustments are initiated. The first response seen is an increase in mouth gape and ventilation volume, which are accompanied by a slowing of heart rate as the oxygen level falls. Cardiac output is maintained at the reduced heart rates by a compensatory increase in stroke volume (the amount of blood pumped per beat). Skipjack tuna showed a stronger slowing of the heart rate and smaller increases in gape and ventilation volume than did yellowfin tuna. This may be a result of their significantly higher resting heart rates, larger gape and higher ventilation volumes.

To check the responses of paralyzed fish, experiments were begun to measure the changes in heart rate of swimming fish exposed to low ambient oxygen. Heart rate is recorded using an FM radio transmitter. Data from yellowfin and skipjack tuna so far show that paralyzed and tabled fish are essentially equally sensitive to changes in low ambient oxygen. Indeed, data from swimming fish show that at almost all levels of reduction in ambient oxygen tuna show cardio-respiratory adjustments. When the cardio-respiratory data from tabled and swimming fish are combined with data on swimming depth obtained by tracking (see project described below) and with data on oxygen levels at depth, it appears that even mild reductions in ambient oxygen level (well above lethal level) may have an effect on the behavior and vertical distribution of skipjack and yellowfin tuna.

Ultrasonic Tracking Extended to Skipjack and Mahimahi

Prior to FY 87 ultrasonic tracking research at the Honolulu Laboratory centered on measuring the vertical and horizontal movements of yellowfin and bigeye tunas associated with fish aggregating devices (FADs). The work involves following fish carrying ultrasonic depth sensitive transmitters using the R/V Kaahele'ale. In the early phases of the research the main objectives have been to determine how FADs influence the vertical and horizontal movements of these species and to determine strategies for optimal FAD placement. The project is a joint effort between Kim Holland of the Hawaii Institute of Marine Biology and Richard Brill of the Honolulu Laboratory. Partial funding is also provided by the U.H. Sea Grant Program.

During FY 87 the project was expanded to gather data on two other commercially important pelagic species often associated with FADs, skipjack tuna and mahimahi. To date 3 skipjack tuna and 3 mahimahi have been caught, tagged with transmitters and followed for up to 48 hours. In general mahimahi have been found to remain closely associated with FADs for up to 8 hours at a time. This contrasts sharply with the behavior of yellowfin tuna which tend to remain near FADs for portions of a day and always leaving the FAD at or before sunset. Also tracked were mahimahi associated with drifting objects. These fish were found to remain tightly associated with these objects for long periods. Mahimahi tracked so far were found to remain almost exclusively at depths of 50 meters or less and to spend long periods (especially during daylight hours) immediately at or slightly below the surface.

The behavior of skipjack tuna around FADs was found to be different from that of skipjack tuna tracked near Hawaii in previous years. FAD associated skipjack tuna tended to remain in the upper 50 meters of the water column, unlike fish not associated with FADs which make regular excursions of several hundred meters up and down the water column.

ARCHIVAL TAG FOR TUNA AND OTHER MARINE FISHES UNDER DEVELOPMENT

In 1984, a group of scientists met at the Southwest Fisheries Center to consider how research efforts should be focused to meet the future needs of tuna management. The meeting was jointly sponsored by the Inter-American Tropical Tuna Commission and the SWFC. Among the key recommendations was the development and use of an archival tag to monitor the movements of many commercially important species, such as tuna and billfish, and protected species such as marine mammals and turtles. Such information could have important implications for fishery development and management and for interpretations of such laws as the Magnuson Fishery Conservation and Management Act and the Marine Mammal Protection Act.

The new tag is called an archival tag because it stores information. It is designed to be programmable and contains a micro-chip. For highly migratory species, such as tunas, it is possible to measure and record parameters needed to track position (times of sunrise and sunset), water temperature and depth. The times of sunrise and sunset would indicate longitude and would require a light sensor. The water temperature would indicate latitude by comparison to reference temperature data for the given longitude. Depth is needed because temperature varies with depth as well as latitude, and also because it is necessary to compensate for attenuation of light with depth.

A contract to design and perform a feasibility study for an archival tag has been granted to Northwest Marine Technology. The company has completed the first phase with a Small Business Innovation Research Grant from the Department of Commerce. The results showed that development of such a tag is feasible and would require $200,000 to produce several prototypes for field testing. Northwest Marine Technology has recently applied for another grant from the Department to continue the prototype development. If successful in their application, Northwest Marine Technology will develop approximately 40 prototypes for the SWFC to field test.

ROLE OF NATURAL MORTALITY IN TUNA MODELS STUDIED

The role of natural mortality in tuna stock assessment models was the subject of a recent review conducted by Fishery Biologist Earl Weber at the SWFC in La Jolla. Natural mortality in tunas is a difficult subject to study for several reasons. First, from the numerical standpoint, the great number of individuals in tuna stocks and the vast geographical ranges they occupy make traditional natural mortality estimation procedures problematic. Determining the causes of natural mortality and at what life stages these causes manifest themselves is difficult also.

Because dead tunas are heavier than sea water and therefore sink, necropsies which can be conducted on mammals, birds, or other fish are impossible. Also, since tunas hydrate (assimilate water) when faced with starvation to maintain their hydrodynamic form, traditional condition factors are meaningless as indicators of health. Acknowledging these problems, this study was intended to examine the various ways in which natural mortality is estimated and enters into the modeling process. This information will ultimately be used to assess the sensitivity of fishery models to simulated changes in natural mortality.

The model chosen for this study was a cohort model because it is widely used in fishery biology and because its output is used as a basis for other population models. Two sets of simulations were conducted. In the first set natural mortality was assumed to be constant but a different value was used in each simulation. In the second set, several vectors of age-specific natural mortality were used. All simulations were conducted with the same catch at age data, the average from the North Pacific albacore fishery for the years 1965 through 1982, and the resulting populations predicted in the simulations were recorded.

The results of the cohort simulations in which natural mortality was assumed constant indicate that the population sizes predicted through cohort analyses were greatly affected by the value of natural mortality even though the model was constrained in such a way that total mortality was equal to the value observed from fishery data in all simulations. Natural mortality was analagous to an interest rate in that high values of natural mortality inflate the population size at each age predicted by the cohort model. The second set of simulations, conducted with age-specific values of natural mortality, indicated the predicted population size by age group was more sensitive to the values of natural mortality for younger age groups that are well represented in the fishery than the values of natural mortality in the older age groups with fewer individuals in the catch subjected to any given level of inflation.

In brief, predicted population levels were affected by the value of natural mortality when assumed to be constant, as well as by the shape of the vector when assumed to be variable. Errors in the output of a cohort model would also, of course, affect other fisheries models based on this output.

PUBLICATIONS

SWFC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS

MAY 1, 1986 TO APRIL 30, 1987

PUBLISHED

Ankenbrandt, Lisa. 1986. The occurrence of young skipjack tuna (Katsuwonus pelamis) in the diet of adult skipjack from the southwestern Atlantic Ocean, pp. 299-300. In: P. E. K. Symons, P. M. Miyake and G. T. Sakagawa (eds.), Proceedings of the ICCAT Conference on the International Skipjack Year Program, Madrid, 1986.

Stomach contents of skipjack tuna captured in 1981-1982 by pole-and-line gear off the southern coast of Brazil were analyzed for the presence of larval and juvenile skipjack. The percent frequency of occurrence, percent number and percent volume were evaluated. Of the 1,041 stomachs that were examined for food, 436 were empty. The mean volume of food in all stomachs analyzed was 36.9 ml, of which 18.9 ml was bait and 18.0 ml was prey. Larval and juvenile skipjack were not present in the diet of adults from this study.

Argue, A. W., P. Kleiber, R. E. Kearney and J. R. Sibert. 1986. Evaluation of methods used by the South Pacific Commission for identification of skipjack population structure, pp. 242-251. In: P. E. K. Symons, P. M. Miyake and G. T. Sakagawa (eds.), Proceedings of the ICCAT Conference on the International Skipjack Year Program, Madrid, 1986.

The use of data from blood genetics, tagging, growth, maturity, juvenile occurrence, and parasite studies for examining skipjack population structure is discussed in light of experience by the Skipjack Survey and Assessment Programme of the South Pacific Commission. Results from analyses of these data support several different hypotheses of skipjack population structure in the Pacific Ocean. This confusion reflects, in part, the limited information content of these data for inferring population structure. Therefore unconditional support for any one hypothesis is misleading, particularly as the potential for fishery interaction differs markedly amongst the hypotheses.

Before choosing a most likely hypothesis of skipjack population structure, gaps in the basic biological data, specifically geographical distribution of spawning and movement of pre-recruits, should be filled. Obtaining comprehensive new data will be costly and time-consuming and will not overcome inherent weaknesses of the traditional methods. There is a need to weigh the benefits to be gained from improved knowledge of population structure against the

benefits to be gained from a better understanding of interaction amongst components of the rapidly expanding fishery for skipjack.

Au, David W. K. 1986. Skipjack population dynamics: Is it qualitatively different from that of other tropical tunas? pp. 189-197. In: P. E. K. Symons, P. M. Miyake and G. T. Sakagawa (eds.), Proceedings of the ICCAT Conference on the International Skipjack Year Program, Madrid, 1986.

Some aspects of the population dynamics of skipjack, yellowfin, and bigeye tuna are compared, and an explanation is sought for the large variations in catches of skipjack and the lack of evidence for decline in its populations following fishing. Compared with yellowfin and bigeye, skipjack is an earlier maturing species with higher natural mortality and more variable populations. It follows that its populations have fewer age classes, are more variable from changes in year class strength and availability, and have higher production/biomass ratios. Skipjack may be considered more 'r-selected' than the other tunas, i.e. the species has probably evolved for greater success in the more variable habitats of the tropical ocean through increased potential for population growth. Skipjack therefore should also be expected to be more opportunistic and migratory in comparison to the other tunas. The tropical tunas, but especially skipjack, appear to have specialized in the energy-expensive foraging strategy of sustained, fast-swimming search over large areas, and this is the likely link between their high metabolic and natural mortality rates. It is further suggested that the higher natural mortality of skipjack is more density dependent than in the other tunas, and that this reduces the effects of fishing.

Au, David W. K. and Robert L. Pitman. 1986. Seabird interactions with dolphins and tuna in the eastern tropical Pacific. The Condor 88:304-317.

Bird flocks associated with dolphins in the eastern tropical Pacific are described from observations obtained during eight cruises that took place from January to March of 1976, 1977, 1979, and 1980. In the northern tropical waters between latitudes 5°N and 30°N, 43% to 53% of bird flocks co-occurred with dolphins. In equatorial and southern subtropical waters between latitudes 5°N to 12°S and in the central Pacific less than 8% of the flocks were associated with dolphins. In northern tropical waters about 70% of dolphin schools associated with flocks were composed of spotted or spotted plus spinner dolphins; conversely, 59% of spotted dolphin and 96% of spotted plus spinner dolphin schools co-occurred with bird flocks. Most large schools of these dolphins were associated with birds, and the number and diversity of bird species increased with dolphin school size. The average species composition of birds in dolphin-associated flocks of northern tropical waters was: boobies

41.7%, Wedge-tailed Shearwaters (Puffinus pacificus) 31.4%, jaegers 12.8%, Sooty Terns (Sterna fuscata) 6%, frigatebirds 3.6%, and others 4.5%. Positive statistical associations were found among these bird species, which are explained by common attraction to food made available by feeding yellowfin tuna. In the southern latitudes and in the central Pacific, flocks were dominated by Sooty Terns, and few flocks were associated with dolphins. These flocks appeared to be associated with skipjack rather than yellowfin tuna.

Goldberg, Stephen R. and David W. K. Au. 1986. The spawning of skipjack tuna from southeastern Brazil as determined from histological examination of ovaries, pp. 277-184. In: P. E. K. Symons, P. M. Miyake and G. T. Sakagawa (eds.), Proceedings of the ICCAT Conference on the International Skipjack Year Program, Madrid, 1986.

A total of 961 skipjack tuna ovaries from southeastern Brazil was examined to determine their reproductive condition. The Brazilian fish were sampled from November 1981 to July 1982 from the coastal area south of Cabo Frio between 22°S and 28°S latitude. A portion of the population was in near spawning condition in November and this condition continued through March. Ovaries obtained during May-June were mainly regressed. The smallest sexually mature female in our sample was 510 mm. The minimum gonad index of mature fish was 30. Histologically mature ovaries represent a wide range of gonad indexes, including ripening and recently spawned conditions.

Graves, John E. and Andrew E. Dizon. 1986. Mitochondrial DNA genetic similarity of Atlantic and Pacific skipjack tuna and its management implications, pp. 237-241. In: P. E. K. Symons, P. M. Miyake and G. T. Sakagawa (eds.), Proceedings of the ICCAT Conference on the International Skipjack Year Program, Madrid, 1986.

Restriction enzyme analysis of mitochondrial DNA (mtDNA) provides the most powerful, practical tool currently available for determining the genetic basis of population structure. This technique applied to skipjack tuna from the Atlantic and Pacific Oceans demonstrated no significant genetic differentiation between fish from different ocean basins although within-sample variation was detected. These results are consistent with the lack of morphological and electrophoretic differentiation of Atlantic and Pacific skipjack tuna found in previous studies and strongly suggest sufficient gene flow between ocean basins to prevent genetic differentiation. As no significant genetic differentiation was exhibited between Atlantic and Pacific skipjack tuna it is unlikely that genetically distinct stocks exist within the Atlantic Ocean. Consequently, any subdivisions of Atlantic skipjack into management units will have to be based upon non-genetic criteria.

Hunter, John R., A. W. Argue, William H. Bayliff, Andrew E. Dizon, Alain Fonteneau, Daniel Goodman, and Gunter R. Seckel. 1986. The dynamics of tuna movements: an evaluation of past and future research. FAO Fish. Tech. Pap. 277, 78 p.

Weaknesses in understanding of tuna distributions and movements have constrained the development of rational management policies. Uncertainties exist in: the selection of management plans and catch and effort data that are representative of a stock; quantification of exchange of adults among management jurisdictions and fishing gears; and identification of the relationships between the environment and tuna movements. This report summarizes a series of discussions between a panel and groups of experts on how to increase understanding of these and other tuna management problems. We discuss the uncertainties in current management policy caused by lack of understanding of tuna movement dynamics. We describe and evaluate the research approaches presently used to describe the movements of tunas--mark and recapture and acoustic tracking--and those which might be used or are just being applied, including new tagging systems, measurement of physiological state and microconstituents of mineralized tissue. Actions needed to improve the knowledge of tuna movements are: 1) establish international arrangements to share tuna movement data, to analyse movements on an oceanwide and worldwide basis and to link international oceanographic programs; 2) increase number and kinds of observations of movements of tuna in the vertical plane; 3) develop and use technology for tracing the actual paths followed by tunas over extended periods and for measuring movements independent of the fishery; and 4) conduct intensive studies on tuna movement dynamics which combine old with the new technologies discussed in the report.

Mendelssohn, R. and Cl. Roy. 1986. Environmental influences on the French, Ivory Coast, Senegalese and Moroccan tuna catches in the Gulf of Guinea, pp. 170-188. In: P. E. K. Symons, P. M. Miyake and G. T. Sakagawa (eds.), Proceedings of the ICCAT Conference on the International Skipjack Year Program, Madrid, 1986.

Both local and broadscale dynamic relationships were studied between catch per unit of effort (CPUE) for yellowfin and skipjack tunas in the Gulf of Guinea, and sea-surface temperatures (SST), and wind speed. The results suggested by a particular temperature during one time period will lead to high CPUE, while at another it will lead to low CPUE. Our analysis was not restricted to where fishing actually occurred.

We used a recently developed algorithm to complete missing CPUE and environmental data. Models were developed for eleven separate sub-areas of the Gulf of Guinea. Details of the method are provided in an appendix. Results from these models suggested that the environmental variables under study reflected an oceanographic process involving upwelling and concentration of nutrients a month prior to good fishing, followed by arrival of relatively warmer waters two weeks prior to good fishing.

We calculated dominant modes of variability for each parameter in time and space by six week and one year periods. The dominant mode for SST showed a space-time movement that was consistent with a recently developed theory of remote forcing in the equatorial Atlantic.

Milsom, W. K., and R. W. Brill. 1986. Oxygen sensitive afferent information arising from the first gill arch of yellowfin tuna. Respir. Physiol. 66:193-203.

Single nerve fiber discharge was recorded from O_2 sensitive receptors in the first gill arch of the yellowfin tuna, thunnus albacares, in vitro. These receptors were innervated by the vagus nerve and increased their discharge in response to decreasing perfusion rate, decreasing perfusion P_{O2} and, in most fibers, to decreasing external P_{O2}. Fibers responding to environmental hypoxia exhibited an exponential increase in discharge to decreasing external P_{O2}, with a sensitivity similar to that exhibited by cat carotid body chemoreceptors. Indirect evidence suggests that these receptors are located near the gill vasculature and are more sensitive to changes in arterial P_{O2} than water P_{O2}. Their response characteristics and hypoxic sensitivity strongly implicate them as the afferent limb in the cardiac responses and perhaps also the ventilatory responses exhibited by tuna to environmental hypoxia.

Myrick, A. C., Jr., A. A. Hohn, J. Barlow, and P. A. Sloan. 1986. Reproductive biology of female spotted dolphins, Stenella attenuata, from the eastern tropical Pacific. Fish. Bull., U.S. 84(2):247-259.

Reproductive parameters were estimated from about 4,700 female spotted dolphins collected in the eastern tropical Pacific from 1973 to 1981. From this sample, specimens for which ages were estimated were divided into two subsets and were used to estimate age-specific rates for the northern offshore stock of this species. The youngest sexually mature individual was 10 years old; the oldest immature was 17 years; the youngest and oldest pregnant individuals were 10 and 35 years, respectively. There was high individual variability in the accumulation of corpora with age; the ovulation rate appears to slow abruptly after the eighth ovulation. Average age at attainment of sexual maturity (ASM) for all years ranged from 10.7 to 12.2 years ($\bar{x}$ = 11.4

years) for two sets of age estimates; no significant temporal change in ASM was detected. Correlation between color phase and state of sexual maturity suggests that color phase may be a good indicator of maturity for this stock. The average annual pregnancy rate was about 0.33; this rate did not change significantly with age. The calving interval was 3.03 years (SE = 0.205). The lactation period was 1.66 years, but there was a significant increase noted in the percent lactating from 1973 to 1981. A low percentage of postreproductive females was found in the sample (0.4%) indicating that reproductive senescence is of little importance in reproductive rates of this stock.

Olson, R. J. and C. H. Boggs. 1986. Apex predation by yellowfin tuna (Thunnus albacares): Independent estimates from gastric evacuation and stomach contents, bioenergetics, and cesium concentrations. Can. J. Fish. Aquat. Sci. 43:1760-1775.

Three approaches for estimating predation by yellowfin tuna (Thunnus albacares) were compared: (1) stomach analysis adjusted for gastric evacuation; (2) food energy required as a function of swimming speed in yellowfin tracked at sea; and (3) food intake needed to maintain observed cesium concentrations. Gastric evacuation data from captive yellowfin were best fit by linear functions of time for four foods. Fish with high lipid content (mackerel, Scomber japonicus) were evacuated at a slower rate (proportion per hour) than smaller fish (smelt, Hypomesus pretiosus), squid (Loligo opalescens), and small fragile fish (nehu, Stolephorus purpureus), all of which had lower lipid contents. Tuna captured in the eastern Pacific had daily rations averaging 3.9% of body mass based on stomach contents and gastric evacuation rates, 5.2% based on bioenergetics estimates, and 6.7% based on the cesium estimate. Swimming costs accounted for one-third to one-half of the energy budget. Annual predation by the eastern Pacific yellowfin population averaged 4.3-6.4 million metric tons during 1970-72, depending on the method used for estimating ration; 34% was frigate tunas (Auxis spp.). High growth and turnover rates (P/B ratios) of tropical tunas in contrast with low conversion and tropic transfer efficiencies suggest a trophic structure that differs from more productive ecosystems.

Reilly, Stephen B. and Jay Barlow. 1986. Rates of increase in dolphin population size. Fish. Bull., U.S. 84(3):527-533.

Annual finite rates of increase in dolphin population size were estimated to vary up to a maximum of 1.09, using simulation, based on ranges in vital rates. Vital rate ranges were defined from values reported in the literature where possible, otherwise by making assumptions about biological or logical limits. Given information on current values, or limits, of one or more vital rates, one can use

the figures presented to determine ranges of possible rates of increase in population size. The highest rates estimated here (up to 1.09) are probably unrealistic, because of the unlikely combinations of high fecundity and low mortality needed to achieve them.

Sakagawa, Gary T. 1986. Skipjack fisheries in the western Atlantic, pp. 99-103. In: P. E. K. Symons, P. M. Miyake and G. T. Sakagawa (eds.), Proceedings of the ICCAT Conference on the International Skipjack Year Program, Madrid, 1986.

Available information on skipjack tuna in the western Atlantic Ocean is reviewed to identify areas where skipjack fisheries might be developed. Areas in the Gulf of Mexico, Caribbean Sea and off southeastern Brazil appear promising areas for development. Utilization of fish aggregating devices and new purse seining techniques are suggested as possible methods for concentrating schools and for catching them more efficiently.

Uchiyama, J. H. 1986. Scombridae, bigeye tuna, pp. 134-135. In R. N. Uchida, and J. H. Uchiyama (eds.), Fishery atlas of the Northwestern Hawaiian Islands. NOAA Tech. Rep. NMFS-38.

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_____. 1986. Scombridae, skipjack tuna, pp. 130-131. In R. N. Uchida, and J. H. Uchiyama (eds.), Fishery atlas of the Northwestern Hawaiian Islands. NOAA Tech. Rep. NMFS-38.

_____. 1986. Scombridae, yellowfin tuna, pp. 132-133. In R. N. Uchida, and J. H. Uchiyama (eds.), Fishery atlas of the Northwestern Hawaiian Islands. NOAA Tech. Rep. NMFS-38.

Wahlen, Bruce E. 1986. Incidental dolphin mortality in the eastern tropical Pacific tuna fishery, 1973 through 1978. Fish. Bull., U.S. 84(3):559-569.

Since the late 1950s, large numbers of dolphins have been killed incidentally in the yellowfin tuna purse seine fishery in the eastern tropical Pacific. Estimates of numbers of dolphins killed incidentally in this fishery from 1973 through 1978 were made previously using a stratified ratio estimator. Previous estimates were revised by reducing the number of strata and incorporating revisions in the data. Revised estimates of total mortality, which are consistently more precise than previous estimates, declined from about 100,000 dolphins per year from 1973 through 1976 to about 25,000 and 15,000 during 1977 and 1978. The decline in estimated mortality between 1976 and 1977 was primarily the result of a decline in the kill rate which

coincided with a significant management action in late 1976. Other examples during the 1964 through 1982 period of such a temporal correspondence between a change in the number or distribution of dolphins killed and legal or management actions are discussed.

Wahlen, Bruce E., G. Jay Walker, Ruth B. Miller, and Charles W. Oliver. 1986. Composition of the incidental kill of small cetaceans in the US purse-seine fishery for tuna in the eastern tropical Pacific, 1982 through 1984. Rep. Int. Whal. Comm. 36:369-374.

Composition of the small cetacean incidental kill by US registered purse-seiners fishing in the eastern tropical Pacific from 1989 to 1984 is reported by area, species, stock, sex, length and reproductive condition. The data were collected by Inter-American Tropical Tuna Commission and National Marine Fisheries Service technicians placed aboard a total of 162 vessel-trips made during these three years. Differences between the data treatment here as opposed to that in two previous papers are discussed.

Weber, J. M., R. W. Brill, and P. W. Hochachka. 1986. Mammalian metabolite flux rates in a teleost: lactate and glucose turnover in tuna. Am. J. Physiol. 250 (Regulatory Integrative Comp. Physiol. 19):R452-R458.

Lactate and glucose turnover rates were measured by bolus injection of [U-^{14}C] lactate and [6-^{3}H] glucose in cannulated lightly anesthetized skipjack tuna, Katsuwonus pelamis. Our goals were 1) to find out whether the high rates of lactate clearance reported during recovery from burst swimming in tuna could be accounted for by high blood lactate fluxes; 2) to extend the observed correlation between lactate turnover and lactate concentration in mammals to a nonmammalian system, and 3) to assess the importance of lactate and glucose as metabolic fuels in tuna and to compare their flux rates with values reported for mammals. Measured lactate turnover rates ranged from 112 to 431 $mol \cdot min^{-1} \cdot kg^{-1}$ and were correlated with blood lactate concentration. Glucose turnover rate averaged 15.3 $mol \cdot min^{-1} \cdot kg^{-1}$. When correcting for body mass and temperature, skipjack tuna has at least as high or even higher lactate turnover rates than those recorded for mammals. Tuna glucose turnover rate is similar to that of mammals but much higher than levels found in other teleosts. Even the highest lactate turnover rate measured in tuna cannot fully account for the rate of blood lactate clearance observed during recovery, suggesting that some of the lactate produced in skeletal muscle must be metabolized in situ. After injection of [U-^{14}C] lactate, <5% of the total blood activity was recovered in glucose, suggesting that the Cori cycle is not an important pathway of lactate metabolism in tuna.

TECHNICAL MEMORANDA

Barlow, Jay and Rennie S. Holt. 1986. Proportions of species of dolphins in the eastern tropical Pacific. NOAA-TM-NMFS-SWFC-56, 44 p.

Overall proportions of the various dolphin species involved in the eastern Pacific tuna fishery are calculated from sightings made from fishing and research vessels. Considerable geographic variability is found in dolphin proportions. Overall species proportions are therefore calculated from a weighted sum of the species proportions within 5-degree geographic strata. Variances in the estimates of these proportions are calculated using bootstrap methods.

The effects of various sighting factors are tested using bootstrap statistics. Estimates of species proportions from data collected on tuna vessels are found to be significantly different from estimates based on research vessel data. Support is given for the superiority of research vessel estimates over those made from tuna vessel sightings. Other factors tested include sighting distance, sighting cue, school size, year, sea state, season, search effort, sighting platform, and distance from previous sighting.

Nearest neighbor analyses show considerable geographic heterogeneity in species compositions, even within 5-degree squares. Schools of like species are clustered together. These results emphasize the importance of random or systematic search patterns in surveys of dolphin species proportions.

Myrick, Albert C., Jr. 1986. Procedures for sampling dolphins: A handbook for shipboard observers. NOAA-TM-NMFS-SWFC-62, 69 p.

ADMINISTRATIVE REPORTS

Barrett, Izadore and E. Charles Fullerton. 1986. Report of the joint NMFS/industry review of plans and operations for research, development and management of the Pacific albacore fishery, December 11 and 12, 1985. Natl. Mar. Fish. Serv., NOAA, La Jolla, California, SWFC Admin. Rep. LJ-86-05, 9 p.

Brill, R. W. (ed.). 1986. Proceedings of the 37th Annual Tuna Conference, May 18-21, 1986. Natl. Mar. Fish. Serv., NOAA, Honolulu, Hawaii, SWFC Admin. Rep. H-86-19, 54 p.

Hudgins, L. L. 1986. Economic issues of the size distribution of fish caught in the Hawaiian skipjack tuna fishery, 1964-82. Natl. Mar. Fish. Serv., NOAA, Honolulu, Hawaii, SWFC Admin. Rep. H-86-14, 16 p.

King, D. M. 1986. Global tuna markets and Hawaii aku. Natl. Mar. Fish. Serv., NOAA, Honolulu, Hawaii, SWFC Admin. Rep. H-86-12C, 15 p.

Kleiber, Pierre and Burt Baker. 1986. Development of catch and effort data base for the North Pacific albacore model. Natl. Mar. Fish. Serv., NOAA, La Jolla, California, SWFC Admin. Rep. LJ-86-26, 21 p.

Majors, A. and F. Miller. 1986. Summary of the 1985 North Pacific albacore fishery data. Natl. Mar. Fish. Serv., NOAA, La Jolla, California, SWFC Admin. Rep. LJ-86-10

Mendelssohn, R. 1986. Environmental influences on skipjack availability. Natl. Mar. Fish. Serv., NOAA, Honolulu, Hawaii, SWFC Admin. Rep. H-86-13C, 14 p.

Sakagawa, G., A. Coan, and N. Bartoo. 1986. Patterns in longline fishery data and bigeye tuna catches. Natl. Mar. Fish. Serv., NOAA, La Jolla, California, SWFC Admin. Rep. LJ-86-28, 24 p.

Sibert, J. 1986. Skipjack fisheries of the southwest Pacific. Natl. Mar. Fish. Serv., NOAA, Honolulu, Hawaii, SWFC Admin. Rep. H-86-11C, 13 p.

PAPERS SUBMITTED FOR PUBLICATION

Akin, Priscilla A. Geographic variation in tooth morphology and dentinal patterns in the spinner dolphin, Stenella longirostris. For consideration for publication in Marine Mammal Science.

Au, David W. and Robert L. Pitman. Seabird relationships with tropical tunas and dolphins. For consideration for publication in Marine Species Interactions.

Bourke, Robert E., James Brock, and Robert M. Nakamura. A study of delayed capture mortality syndrome in skipjack tuna, Katsuwonus pelamis. For consideration for publication in the Journal of Fish Diseases.

Fiedler, Paul C. and Hannah J. Bernard. Tuna aggregation and feeding near fronts observed in satellite imagery. For consideration for publication in Continental Shelf Research.

Graves, John E. and Andrew E. Dizon. Mitochondrial DNA sequence similarity of Atlantic and Pacific albacore tuna. For consideration for publication in Canadian Journal of Fisheries and Aquatic Sciences.

Hochachka, P. W. and R. W. Brill. A new analysis of the tuna burn problem. For consideration for publication in the Journal of Food Science.

Perrin, W. F., E. D. Mitchell, J. G. Mead, D. K. Caldwell, M. C. Caldwell, P. J. H. van Bree and W. H. Dawbin. Revision of the spotted dolphins, Stenella spp. For consideration for publication in Marine Mammal Science.